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A novel hybrid MCDM approach to evaluate universities based on student perspective

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Abstract

University rankings are an essential source of comparisons between universities according to specific combinations of criteria. International or national rankings have an increasing impact on higher education institutions, stakeholders, and their environments. Thereby, on behalf of effective decision-making, university-ranking efforts should be a process involving some conflicting criteria and uncertainties in a more sensitive manner. This study presents a detailed university evaluation procedure under certain service criteria via multi-criteria decision-making (MCDM) methodologies and provides an appropriate clustering of universities according to teaching and research factors. A hierarchical cluster-based Interval Valued Neutrosophic Analytic Hierarchy Process (IVN-AHP) integrated VIKOR methodology that includes two stages, clustering and ranking, is proposed for the university evaluation problem. The hierarchical clustering method is performed using teaching and research factors in the first stage. The second stage addresses the determination weights of service criteria through IVN-AHP and the ranking of universities by using VIKOR according to service criteria under determined clusters. This study, in which the proposed methodology is applied to Turkish universities, is the most comprehensive in terms of the number of universities evaluated and participating students. Furthermore, the integration of IVN-AHP and VIKOR to solve MCDM problems is presented for the first time. This study differs from other studies in terms of novelties both methodological-based and application based. Moreover, categorizing universities with similar characteristics into groups using cluster analysis and ranking them with the MCDM methodology provide a more realistic and effective interpretation of the results.

Keywords University ranking problem · Neutrosophic numbers · AHP · VIKOR · Higher education · Turkey

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Introduction

Higher education institutions are in competition to enhance regional growth and support global development strategies with the necessary highly qualified personnel and research (Al-Turki & Duffuaa, 2003; Ho et al., 2006). In such a competition among educational institutions, the awareness that is necessary to evaluate the quality of institutions effectively and objectively contributes to the increase in performance. Prospective students and their families consider university rankings to select a suitable university in terms of time, career prospects, and financial situations (Griffith & Rask, 2007). Moreover, scientists, with whom scientific cooperation can benefit from many university rankings when deciding on the university they will go to for research. Therefore, evaluating the organizational effectiveness of higher education institutions is becoming more important to governments, universities, researchers, and students. In the context of organizational effectiveness, determining the degree to which an organization reaches its objectives is complex. The number of resources to produce a unit of output is difficult to measure in universities with multiple inputs, outputs, and stakeholders (Ball & Halwachi, 1987). Fortunately, depending on developments in higher education, as long as the concepts of quality, efficiency, and accountability are more visible, performance evaluation processes can be managed more accurately in terms of teaching, research, and service quality indicators.

Higher education, especially in universities, involves many managerial and practical dimensions, such as human activities, limited resources, numerous actors, intense communication, etc., which need to be managed simultaneously. Due to the essentially conflicting criteria, the university ranking problem is a complex evaluation procedure that consists of more than one criterion by its nature (Azma, 2010). Therefore, multi-criteria decision-making (MCDM) approach, a branch of operations research and a systematic decision-making procedure on complex problems, can be considered an appropriate solution to handle the university ranking problem through evaluating multiple conflicting criteria. It is seen that some tangible quality criteria, which are measurable in units, are used in university performance improvement studies, such as teaching, research (Barnabè & Riccaboni, 2007; Wu et al., 2012), and international outlook (Aliyev et al., 2020). Since tangible quality indicators are not sufficient to evaluate universities in the context of organizational theory, service quality indicators should also be included to make a more comprehensive evaluation (Karadağ & Yücel, 2020). Service quality indicators that cannot be measured in units directly are called intangible criteria and are defined as stakeholders' satisfaction (students, researchers, lecturer, etc.). The service quality of universities should be improved to ensure the satisfaction of all stakeholders due to increasing competition in line with the increasing number of universities.

Due to the intangible nature of service quality indicators, the evaluation of these indicators depends directly on the perception of stakeholders. However, the expectations of stakeholders evolve according to the promised resources, their personal networks, and their status quo. Consequently, ranking universities that have different socioeconomic developments and provide disproportional opportunities according to perceived quality may present unfair results.

Researchers and theoreticians have focused on the university ranking problem and its extensions over the years. Using different optimization and sorting techniques for the university ranking problem is one of the most studied topics in the literature. Still, there are a limited number of studies on defining criteria and determining the weights of criteria. Therefore, this problem is discussed in this study.

Considering the above issues regarding the stakeholders' satisfaction and academic process improvement, this study presents a two-stage evaluation methodology for the university ranking problem. In the first stage, universities are clustered according to tangible factors, before ranking universities based on student satisfaction. These tangible factors, the foundation year, the number of academicians, the number of students per academician, the number of citations per academician, and the number of academic outputs per academician, are accessible before the choice of a university. Such factors are preferred because of their representation strength of the promised resources in higher education. In this way, it is ensured that universities with common characteristics are ranked according to the satisfaction of students who have similar expectations and prefer similar universities. Furthermore, thanks to clustering, the university ranking methodology can be applied in a more sensitive, realistic, and effective manner.

In the second, a hybrid MCDM model is employed to rank universities by considering the following service quality criteria**:** "learning experience", "campus life", "academic support", "management", "learning opportunities and resources", and "personal development and career support". In the MCDM methodology, the criteria are weighted by the Interval Valued Neutrosophic Analytic Hierarchy Process (IVN-AHP) based on student opinion; then, the universities are ranked using Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) based on student satisfaction. In this context, VIKOR is extended with IVN-AHP for the first time in the literature.

VIKOR, one of the MCDM methods, focuses on the selection of the most suitable one among a set of alternatives under conflicting criteria or the ranking of the alternatives (Büyüközkan & Ruan, 2008). VIKOR enables decision-makers to identify the compromise solution by evaluating conflicting criteria to reach a final decision. Compromising ranking determines a compromised solution, close to the ideal, that provides maximum 'group benefit' for the majority and minimum individual regrets (San Cristóbal, 2012). In this study, VIKOR is extended with IVN-AHP to obtain more systematic criteria weight determination and alternative evaluation.

To determine the relative importance of the criteria in the decision-making process, the criteria should be weighted according to the preferences of the decision-makers. Therefore, IVN-AHP is used to determine the weight of the criteria in this study. AHP is one of the MCDM methodologies based on a pairwise comparison of criteria and alternatives (Çavdur et al., 2018), enabling more appropriate decisions with a formal and systematic decision-making process. It has a structure that simplifies complex problems. Due to the nondeterministic environment, complexity and unreliable information arise when experts with different interests, loyalties, and cultures interact with a particular project or program to evaluate alternatives or criteria (Abdel-Basset et al., 2019). The method sometimes does not reflect the human way of thinking, even if it receives information from experts (Ayyildiz & Taskin Gumus, 2020). Therefore, IVN-AHP emerged by combining AHP with neutrosophic logic. Comparison values in IVN-AHP are used in a range of values, unlike AHP, where net values are used. Neutrosophic logic provides a more flexible tool for experts while expressing their opinions with inconsistent and incomplete information under uncertainty, especially when experts' opinions are taken with linguistic evaluations in decision-making problems (Gulum et al., 2021). Therefore, AHP is extended with a neutrosophic set, which was first proposed by (Smarandache, 1999).

This study has three main contributions to the literature from different aspects. (i) The first methodological contribution is, to the best of our knowledge, the use of the integrated application of IVN-AHP and VIKOR. (ii) The second methodological contribution is the consideration of both tangible and intangible factors for university ranking thanks to performing clustering and MCDM consecutively. (iii) From the practical aspect, this study is the most comprehensive in terms of the number of evaluated universities and participating students. In this context, such a study that integrates a clustering method to the university ranking problem through MCDM emphasizes reflecting student requirements to universities in terms of universities assessment in a more sensitive manner and the importance of evaluation indicators determined by students with a procedure easy to understand and apply. Moreover, the neutrosophic set provides a representation of knowledge to cope with uncertainty and lack of information inherent in such problems that involve many students' opinions of different faculties in evaluating the indexes for university rankings.

The rest of the paper is structured as follows. Section "Literature review" presents a review of the literature on the university ranking problem. The proposed integrated methodology is given in section "Proposed methodology". The application of the proposed methodology for Turkish universities is presented in section "The application". In section "Discussions and implications", the discussion and implications are provided. Finally, the conclusions are presented in section "Conclusion".

Literature review

The literature review focuses on two subjects; the first focus is studies related to a better understanding of the factors affecting the choice of a university, and the second one is studies related to the evaluation of higher education institutions according to different perspectives. Additionally, since this study integrates clustering and MCDM through a holistic framework methodology for the university ranking problem, studies related to clustering or classification of universities are also reviewed.

Factors affecting university choice have been an attractive topic for researchers, especially over the last two decades. Soutar and Turner (2002) applied conjoint analysis to examine important factors affecting the choice of a university in Australia. Briggs (2006) surveyed to detect the determinants of undergraduate education preferences and conducted a factor analysis to obtain more meaningful results and categorize the determinants of undergraduate education institution choice. Briggs and Wilson (2007) examined the factors that affect the choice of a university in Scotland, especially the 'Information Supplied by Universities' and 'Cost of the Package' factors. It was observed that these factors were ranked 10th and 20th among 22 factors considered in university choice. Simões and Soares (2010) conducted a quantitative analysis to determine the factors affecting students' decisions for university selection. They conducted a questionnaire survey on 1641 students who applied to the university for the first time. Sojkin et al. (2012) performed a survey with 1420 Polish students to determine the factors affecting university choice and examine how these factors differ according to personal information such as gender, age, and family income level.

Recently, parallel to the increase in competition among universities, studies related to their evaluation have gained increasing attention from different perspectives such as overall performance (Aliyev et al., 2020; Nazari-Shirkouhi et al., 2020; Wu et al., 2012; Zolfani & Ghadikolaei, 2013), research capacity (Duc et al., 2020; Su et al., 2020), innovation (Chen & Chen, 2010), a department of a university (Muhammad et al., 2021), sustainability (Arora et al., 2020; Puente et al., 2020), lean philosophy (Kazancoglu & Ozkan-Ozen, 2019; Klein et al., 2021), and student viewpoint (Castro-Lopez et al., 2021; Goyal et al., 2021; Kabak & Dağdeviren, 2014; Nanath et al., 2021; Nojavan et al., 2021).

One of the most common perspectives in ranking universities is the overall performance. Wu et al. (2012) applied a hybrid AHP-VIKOR method to rank 12 private universities in Taiwan according to their performance from academicians' viewpoint. They structured a 3-level criteria hierarchy based on the performance evaluation structure developed by the Taiwan Assessment and Evaluation Association. Zolfani and Ghadikolaei (2013) proposed a model in which balance score card (BSC) and MCDM techniques were used to evaluate performances of private universities in Iran. The Decision Making Trial and Evaluation Laboratory (DEMATEL) was used to reveal the relationships among the perspectives of BSC, the Analytic Network Process (ANP) was used to determine the importance of the criteria, and VIKOR was used to obtain the final ranking of the universities. On behalf of improving this methodology, both Özdemir and Tüysüz (2017) and Nazari-Shirkouhi et al. (2020) integrated fuzzy logic into BSC-MCDM to cope with the ambiguity of decision-makers. Aliyev et al. (2020) applied a Fuzzy AHP model to rank five universities in the United Kingdom regarding four criteria.

Another common topic about university ranking is research capacity. Duc et al. (2020) proposed a new MCDM model that uses improved arithmetic operations of generalized fuzzy numbers. They applied this model to evaluate research capacity at Vietnam University. Su et al. (2020) proposed a model that uses MCDM and output-oriented nonradial super efficiency Data Envelopment Analysis (DEA) to evaluate the research efficiency of Chinese universities. There are few applications in the literature on university ranking problems based on the perspective of innovation. Chen and Chen (2010) emphasized that university innovation could not be measured only by academic research papers, but also other factors such as 'number of chair professors' and 'international academic interaction'. Therefore, the authors proposed a new MCDM model to evaluate universities' innovation performance. They formed a decision support system that combines DEMATEL to reveal the relationships between criteria, fuzzy ANP to determine the criteria weights, and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to rank the alternatives. Muhammad et al. (2021) proposed an MCDM model to evaluate the usability of academic websites of higher education institutions. They used fuzzy AHP to determine criteria weights and compare alternatives.

A brand new perspective is sustainability. Puente et al. (2020) proposed an integrated model for quality assessment and sustainability assessment for higher education institutions in Europe. A fuzzy DEMATEL model was used to reveal the relationships between criteria, a fuzzy ANP model was used to determine the weights of criteria, and finally, a Fuzzy Inference System was used to make final evaluations of higher education institutions. Arora et al. (2020) Arora et al. applied fuzzy AHP to prioritize sustainability drivers of higher education institutions and revealed that environmental practices and social responsibility are the most critical drivers. Likewise, another challenging topic is lean philosophy. Kazancoglu and Ozkan-Ozen (2019) proposed the fuzzy DEMATEL model to detect and rank important wastes in higher education institutions from the academic staff perspective. Klein et al. (2021) determined wastes in higher education institutions and applied AHP to prioritize them and concluded that the most important wastes are loss of knowledge and overprocessing.

Evaluating universities from students' viewpoints has been much sought after, especially in the last few years. Kabak and Dağdeviren (Kabak & Dağdeviren, 2014) applied a hybrid MCDM method to understand Industrial Engineering students' way of thinking in university choice. They used the ANP method to determine the weights of the criteria and the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to obtain the final ranking. Goyal et al. (2021) contributed to this topic by considering the uncertainty of student judgments through Fuzzy AHP. Nanath et al. (2021) investigated differences in university choice factors pre and after the COVID-19 pandemic via one-way multivariate analysis of variance (MANOVA) and ranked universities via AHP. Nojavan et al. (2021) focused on academic units' performance from students' viewpoints in higher education. Hence, they proposed a model in which students' opinions were received by a fuzzy SERVQUAL questionnaire, the criteria weights were determined by Fuzzy AHP, the final ranking was obtained by Fuzzy TOPSIS, and the efficiency of the units were revealed by Fuzzy DEA. Introducing a new perspective, Castro-Lopez et al. (2021) proposed a hybrid AHP-Fuzzy Inference Systems method so that the reasons for university dropout and factors that affect the intention to remain in the university can be better understood.

As mentioned above, studies related to clustering or classification of universities for different purposes were also reviewed. For example, Valadkhani and Worthington (2006) clustered 36 universities in Austria according to research capacity per academic staff, Erdoğmuş and Esen (2016) clustered Turkish universities according to institutional size and performance by using hierarchical cluster analysis, Wang and Zha (2018) implemented three clustering methods to Chinese universities to cluster them according to systematic diversity, Perchinunno and Cazzolle (2020) applied clustering analysis to 780 international universities and revealed four groups according to sustainability, and etc.

A comprehensive literature review reveals that MCDM-based approaches are often used to solve university evaluation problems from different perspectives. Moreover, studies dealing with university evaluation from the student perspective do not include teaching and research factors. The evaluation of similar universities is not addressed in such studies, and the number of included universities has always been limited. Different MCDM methodologies are employed to handle the university ranking problem, especially for weighting criteria. In this study, the VIKOR methodology is extended with IVN-AHP to solve the university ranking problem.

This study considers both student satisfaction criteria and widespread teaching and research characteristics by focusing on these research gaps. Primarily, universities are clustered according to teaching and research characteristics, and then, universities are ranked within each cluster according to students' satisfaction. In this way, instead of ranking a large number of universities at once, it is possible to perform the proposed MCDM method to rank fewer universities within the clusters. A more sensitive, realistic, and effective evaluation of similar universities is obtained. A novel MCDM methodology that integrates IVN-AHP and VIKOR is presented for the first time in the decision-making literature. Furthermore, to the best of the authors' knowledge, it is the most comprehensive study in terms of the number of universities considered and the number of students who participated.

Proposed methodology

The proposed methodology consists of two stages. At the first stage, universities are divided into different clusters via hierarchical clustering based on teaching and research characteristics. At the second stage, the predetermined criteria, which have been used to rank universities in a previous survey (Karadağ & Yücel, 2020), are weighted using the IVN-AHP methodology based on opinions taken from students from different universities. VIKOR is then employed to evaluate and rank the universities in each cluster using these weights. The methodology also has a subsidiary stage to compare cluster-based rankings with holistic rankings. The proposed integrated methodology is illustrated in Fig. 1 and is theoretically detailed in the following subsections.

Hierarchical clustering

Dividing data into meaningful or useful groups ensures that algorithms generate more significant outputs. Based on the groups, formed for understanding (objects share common characteristics) or utility (characterizing clusters in terms of cluster prototypes), the outputs better reflect the people's ways of analyzing and describing the natural structure of the domain (Tan & Steinbach, 2006).

Cluster analysis (or clustering) is one of the most common ways to group objects based on several measurements made on each object individually. Within the frame of understanding the objects in the same groups, the key idea is to guarantee within-group similarity, and hence dissimilarity among the groups. For this purpose, there are two general types of clustering algorithms: hierarchical clustering and nonhierarchical clustering (Köhn & Hubert, 2015).

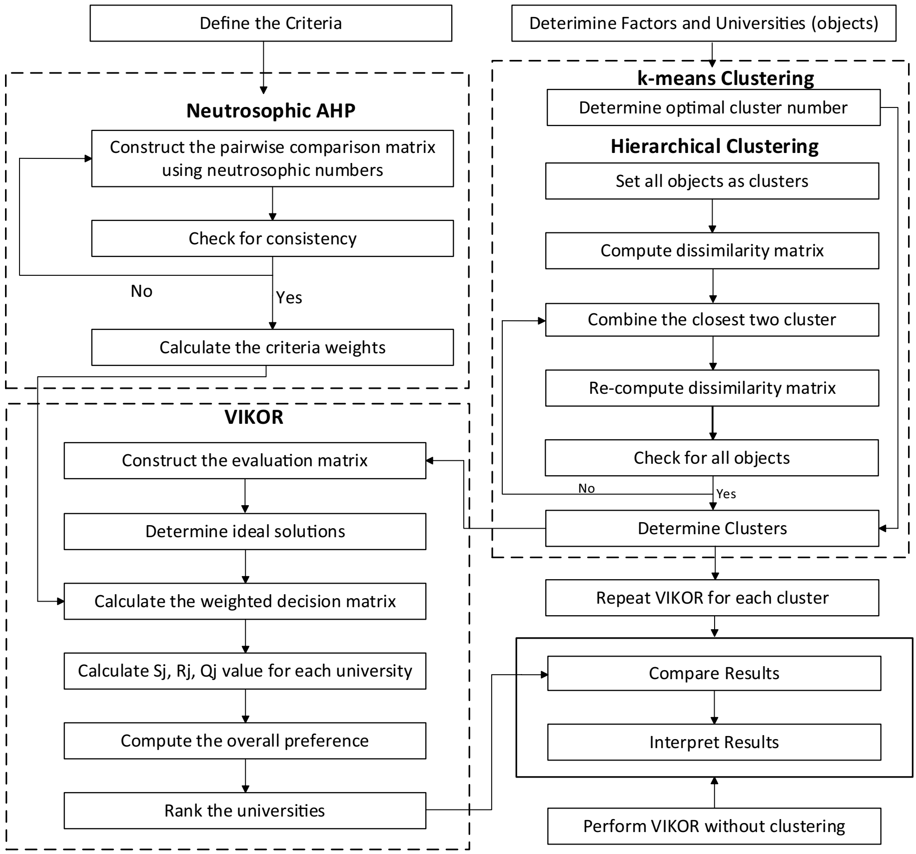


Fig. 1 The proposed methodology

Nonhierarchical algorithms produce nonoverlapping clusters, meaning an object belongs to one cluster. The algorithm requires a prespecified cluster number to assign an object to one of the clusters. However, hierarchical algorithms arrange the clusters into a natural hierarchy. This natural hierarchy produces a set of nested clusters in the form of a tree. Additionally, a prespecified cluster number is no need for hierarchical algorithms when useful in the absence of the information likely groups in the data.

In this study, to model each cluster separately rather than the entire heterogeneous dataset, a hierarchical clustering algorithm was used to group universities with similar teaching and research characteristics. Then, an individual comparison of each cluster is drawn through the proposed decision-making method.

The hierarchical clustering algorithm can be either agglomerative or divisive. The algorithm used in this study is agglomerative, which has widespread use, begins with n clusters (equal to the numbers of the object in the dataset) and continues progressively merging the two most similar (nearest) clusters untill all objects belong to one cluster. The divisive clustering algorithm has an inverse logic with the agglomerative algorithm. A formal procedure for the hierarchical clustering is expressed in Algorithm 1 (González-Cabrera et al., 2021).

Algorithm. 1 Agglomerative hierarchical clustering algorithm.

1. Set all objects in data as individual clusters.
2. Compute the dissimilarity between each possible cluster pair.

Repeat

3. Combine the closest (similar) two clusters to form one cluster.
4. Update the objects in data and count the combined objects as a single.
5. Re-compute dissimilarity between each new cluster pair using reduced data.

Until all objects are assigned to one cluster.

Clusters have one or more objects. Hence, once the first iteration is applied and the nearest single objects are combined, the distance calculation between any two clusters (or a cluster and an object) is now needed to combine clusters. This distance calculation relies on the closeness of two clusters quantified by various linkage measures, such as minimum distance, average distance, centroid distance, and Ward's method. On the other hand, the dissimilarity between two objects i and j when evaluating linkage between clusters is measured by a distance metric such as Euclidean, Cosine, Pearson's correlation, and Minkowski.

Interval-valued neutrosophic analytical hierarchy process (IVN-AHP)

The neutrosophic logic was developed by Smarandache (1998) as a more generalized version of fuzzy sets to cope with indeterminancy and ambiguity more comprehensively by extending fuzzy logic with a novel function named "uncertainty" (Kahraman et al., 2020). Three functions are used to define a neutrosophic set $\widetilde{\widetilde{A}}$ in the universe E. These functions are represented as $T_A(x)$ for truth-membership function, $I_A(x)$ for indeterminacy-membership function, and $F_A(x)$ falsity membership function (Bolturk & Kahraman, 2018).

Definition 1 A single-valued neutrosophic number (SVNN) $\tilde{\ddot{S}}$ is defined as follows (Biswas et al., 2014; Bolturk & Kahraman, 2018):

$$\tilde{\ddot{S}} = \left\{x, \left(T_S(x), I_S(x), F_S(x)\right) >: x \in E, \left(T_S(x), I_S(x), F_S(x) \in]^-0, 1[^+\right)\right\} \quad (1)$$

Definition 2 An interval-valued neutrosophic number (IVNN) $\tilde{\ddot{A}}$ is defined as follows:

$$\tilde{\ddot{A}} = \left\{x, \left[T_A^L(x), T_A^U(x)\right], \left[I_A^L(x), I_A^U(x)\right], \left[F_A^L(x), F_A^U(x)\right]; x \in E\right\} \quad (2)$$

Similar to SVNNs, the values of the functions must be between 0 and 1.

Definition 3 IVNN $\tilde{\ddot{A}}$ is deneutrosophicated by (Bolturk & Kahraman, 2018):

$$\mathfrak{D}(x) = \left(\frac{\left(T_A^L + T_A^U\right)}{2} + \left(1 - \frac{\left(I_A^L + I_A^U\right)}{2}\right)\left(I_A^U\right) - \left(\frac{F_A^L + F_A^U}{2}\right)\left(1 - F_A^U\right)\right) \quad (3)$$

Definition 4 Let $\tilde{\ddot{\alpha}} = \left[T_a^L, T_a^U\right], \left[I_a^L, I_a^U\right], \left[F_a^L, F_a^U\right]$ and $\tilde{\ddot{\beta}} = \left[T_\beta^L, T_\beta^U\right], \left[I_\beta^L, I_\beta^U\right], \left[F_\beta^L, F_\beta^U\right]$ be two IVNNs. Basic mathematical operations on $\tilde{\ddot{\alpha}}$ and $\tilde{\ddot{\beta}}$ are given as follows (Kahraman et al., 2020; Karaşan et al., 2020):

$$\tilde{\ddot{a}} \oplus \tilde{\ddot{b}} = \left\langle \left[T_a^L + T_\beta^L - T_a^L T_\beta^L,\ T_a^U + T_\beta^U - T_a^U\, T_\beta^U\right], \left[I_a^L I_\beta^L, I_a^U\, I_\beta^U\right], \left[F_a^L F_\beta^L, F_a^U F_\beta^U\right]\right\rangle \quad (4)$$

$$\tilde{\ddot{a}} \ominus \tilde{\ddot{b}} = \left\langle \left[T_a^L - F_\beta^U, T_a^U - F_\beta^L\right], \left[Max\left(I_a^L, I_\beta^L\right), Max\left(I_a^U, I_\beta^U\right)\right], \left[F_a^L - T_\beta^U, F_a^U - T_\beta^L\right]\right\rangle \quad (5)$$

$$\tilde{\ddot{a}} \otimes \tilde{\ddot{b}} = \left\langle \left[T_a^L T_\beta^L, T_a^U T_\beta^U\right], \left[I_a^L + I_\beta^L - I_a^L I_\beta^L, I_a^U + I_\beta^U - I_a^U I_\beta^U\right], \left[F_a^L + F_\beta^L - F_a^L F_\beta^L, F_a^U + F_\beta^U - F_a^U F_\beta^U\right]\right\rangle \quad (6)$$

$$\left(\tilde{\ddot{a}}\right)^\lambda = \left\langle \left[\left(T_a^L\right)^\lambda, \left(T_a^U\right)^\lambda\right], \left[\left(I_a^L\right)^\lambda, \left(I_a^U\right)^\lambda\right], \left[1 - \left(1 - F_a^L\right)^\lambda, 1 - \left(1 - F_a^U\right)^\lambda\right]\right\rangle; \lambda \geq 0 \quad (7)$$

$$\lambda\tilde{\ddot{\alpha}} = \left\langle \left[1 - \left(1 - T_a^L\right)^\lambda, 1 - \left(1 - T_a^U\right)^\lambda\right], \left[\left(I_a^L\right)^\lambda, \left(I_a^U\right)^\lambda\right], \left[\left(F_a^L\right)^\lambda, \left(F_a^U\right)^\lambda\right]\right\rangle; \lambda \geq 0 \quad (8)$$

The AHP method, whose fundamentals were firstly proposed by Myers and Alpert (1968). Then Saaty systematized and developed based on the logic of structuring a problem in hierarchical structure (Thor et al., 2013). The AHP methodology sometimes fails to reflect opinions from decision-makers because of indeterminancy and ambiguity in information (Ayyildiz et al., 2020). IVN-AHP can be used to handle indeterminacy and ambiguity with three functions to effectively integrate human thought into the decision-making process. In this study, the students' satisfaction factors are weighted using the IVN-AHP methodology. The application steps of the methodology are given below.

Step 1. The criteria and evaluation scale are determined.

Step 2. Pairwise comparison matrix $\left(\tilde{\ddot{P}}\right)$ is constructed via linguistic terms. Then, the evaluation scale is used to convert the linguistic terms to the IVNN numbers as given in Eq. 9. Deneutrosophication is performed for the pairwise comparison matrix to analyze the consistency of the matrix.

$$\tilde{\ddot{P}}_C = \begin{bmatrix} [T^L_{11}, T^U_{11}], [I^L_{11}, I^U_{11}], [F^L_{11}, F^U_{11}] & \cdots & [T^L_{1m}, T^U_{1m}], [I^L_{1m}, I^U_{1m}], [F^L_{1m}, F^U_{1m}] \\ \vdots & \ddots & \vdots \\ [T^L_{m1}, T^U_{m1}], [I^L_{m1}, I^U_{m1}], [F^L_{m1}, F^U_{m1}] & \cdots & [T^L_{mm}, T^U_{mm}], [I^L_{mm}, I^U_{mm}], [F^L_{mm}, F^U_{mm}] \end{bmatrix} \tag{9}$$

m is the number of criteria.

Step 3. The normalized importance weights of the criteria are calculated by the following steps.

Step 3.1. Sum the values in each column as in Eq. 10:

$$\tilde{\ddot{S}}_{ij} = \left\langle \left[\sum_{k=1}^{m} T^L_{kj}, \sum_{k=1}^{m} T^U_{kj}\right], \left[\sum_{k=1}^{m} I^L_{kj}, \sum_{k=1}^{m} I^U_{kj}\right], \left[\sum_{k=1}^{m} F^L_{kj}, \sum_{k=1}^{m} F^U_{kj}\right] \right\rangle \tag{10}$$

Step 3.2. The upper limit value for each parameter is determined and each term is divided by its corresponding element to obtain $\tilde{\ddot{N}}_{ij}$ values by Eq. 11:

$$\tilde{\ddot{N}}_{ij} = \left\langle \left[\frac{T^L_{kj}}{\sum_{k=1}^{m} T^U_{kj}}, \frac{T^U_{kj}}{\sum_{k=1}^{m} T^U_{kj}}\right], \left[\frac{I^L_{kj}}{\sum_{k=1}^{m} I^U_{kj}}, \frac{I^U_{kj}}{\sum_{k=1}^{m} I^U_{kj}}\right], \left[\frac{F^L_{kj}}{\sum_{k=1}^{m} F^U_{kj}}, \frac{F^U_{kj}}{\sum_{k=1}^{m} F^U_{kj}}\right] \right\rangle \tag{11}$$

Then, the matrix is constructed:

$$\tilde{\ddot{P}} = \begin{bmatrix} \left\langle \begin{matrix} \left[\frac{T^L_{11}}{\sum_{k=1}^{m} T^U_{kj}}, \frac{T^U_{11}}{\sum_{k=1}^{m} T^U_{kj}}\right], \\ \left[\frac{I^L_{11}}{\sum_{k=1}^{m} I^U_{kj}}, \frac{I^U_{11}}{\sum_{k=1}^{m} I^U_{kj}}\right], \\ \left[\frac{F^L_{11}}{\sum_{k=1}^{m} F^U_{kj}}, \frac{F^U_{11}}{\sum_{k=1}^{m} F^U_{kj}}\right] \end{matrix} \right\rangle & \cdots & \left\langle \begin{matrix} \left[\frac{T^L_{1m}}{\sum_{k=1}^{m} T^U_{kj}}, \frac{T^U_{1m}}{\sum_{k=1}^{m} T^U_{kj}}\right], \\ \left[\frac{I^L_{1m}}{\sum_{k=1}^{m} I^U_{kj}}, \frac{I^U_{1m}}{\sum_{k=1}^{m} I^U_{kj}}\right], \\ \left[\frac{F^L_{1m}}{\sum_{k=1}^{m} F^U_{kj}}, \frac{F^U_{1m}}{\sum_{k=1}^{m} F^U_{kj}}\right] \end{matrix} \right\rangle \\ \vdots & \ddots & \vdots \\ \left\langle \begin{matrix} \left[\frac{T^L_{m1}}{\sum_{k=1}^{m} T^U_{kj}}, \frac{T^U_{m1}}{\sum_{k=1}^{m} T^U_{kj}}\right], \\ \left[\frac{I^L_{m1}}{\sum_{k=1}^{m} I^U_{kj}}, \frac{I^U_{m1}}{\sum_{k=1}^{m} I^U_{kj}}\right], \\ \left[\frac{F^L_{m1}}{\sum_{k=1}^{m} F^U_{kj}}, \frac{F^U_{m1}}{\sum_{k=1}^{m} F^U_{kj}}\right] \end{matrix} \right\rangle & \cdots & \left\langle \begin{matrix} \left[\frac{T^L_{mm}}{\sum_{k=1}^{m} T^U_{kj}}, \frac{T^U_{mm}}{\sum_{k=1}^{m} T^U_{kj}}\right], \\ \left[\frac{I^L_{mm}}{\sum_{k=1}^{m} I^U_{kj}}, \frac{I^U_{mm}}{\sum_{k=1}^{m} I^U_{kj}}\right], \\ \left[\frac{F^L_{mm}}{\sum_{k=1}^{m} F^U_{kj}}, \frac{F^U_{mm}}{\sum_{k=1}^{m} F^U_{kj}}\right] \end{matrix} \right\rangle \end{bmatrix} \tag{12}$$

Step 3.3. The arithmetic mean is determined for each row to obtain the neutrosophic importance weight vector 13:

$$\tilde{\ddot{W}}_j = \begin{pmatrix} \frac{\left[\sum_{k=1}^{m} \frac{T_{1j}^{L}}{\sum_{k=1}^{m} T_{kj}^{U}}, \sum_{k=1}^{m} \frac{T_{1j}^{U}}{\sum_{k=1}^{m} T_{kj}^{U}}\right]}{m}, \\ \frac{\left[\sum_{k=1}^{m} \frac{I_{1j}^{L}}{\sum_{k=1}^{m} I_{kj}^{U}}, \sum_{k=1}^{m} \frac{I_{1j}^{U}}{\sum_{k=1}^{m} I_{kj}^{U}}\right]}{m}, \\ \frac{\left[\sum_{k=1}^{m} \frac{F_{1j}^{L}}{\sum_{k=1}^{m} F_{kj}^{U}}, \sum_{k=1}^{m} \frac{F_{1j}^{U}}{\sum_{k=1}^{m} F_{kj}^{U}}\right]}{m} \end{pmatrix} \quad j = 1, 2, \dots, m \tag{13}$$

Step 4. The importance weight vector is deneutrosophicated to determine the final weight of the criteria.

VIKOR

The VIKOR method was first presented by Opricovic (1998) for multi-criteria optimization of complex systems. VIKOR is a method that allows determining a consensual ranking and achieving a compromise solution according to the specified criteria. In the method, alternatives are evaluated according to criteria and a ranking is obtained by calculating proximity values to the ideal alternative (Tayyar & Arslan, 2013). The steps of VIKOR are given below:

Step 1. The decision matrix is established to evaluate alternatives. Let x_{ij} is the value of alternative i with respect to criterion j.

Step 2. The best x_j^+ and the worst x_j^- value for each criterion is determined as follows:

$$x_j^+ = \max_{\mathrm{i}} \left(x_{ij}\right); x_j^- = \min_{i} \left(x_{ij}\right) \quad \text{for benefit criteria} \tag{14}$$

$$x_j^+ = \min_{i} \left(x_{ij}\right); \quad x_j^- = \min_{i} \left(x_{ij}\right) \quad \text{for cost criteria} \tag{15}$$

Step 3. S_i and R_i are calculated using Eqs. 16 and 17, respectively.

$$S_i = \sum_{j=1}^{m} w_j \left(x_j^+ - x_{ij}\right) \Big/ \left(x_j^+ - x_j^-\right) \tag{16}$$

$$R_i = \max_{j} \left[w_j \left(x_j^+ - x_{ij}\right) \Big/ \left(x_j^+ - x_j^-\right)\right] \tag{17}$$

where w_j is the weight of criterion j determined by IVN-AHP.

Step 4. Q_i is computed:

$$Q_i = v \frac{\left(S_i - S^+\right)}{\left(S^- - S^+\right)} + (1 - v) \frac{\left(R_i - R^+\right)}{\left(R^- - R^+\right)} \tag{18}$$

where $S^{+} = \min_{i} S_i; S^{-} = \max_{i} S_i$ and $R^{+} = \min_{i} R_i; R^{-} = \max_{i} R_i$. v and $(1 - v)$ represent the weight of strategy of maximum group utility and individual regret, respectively.

Step 5. Alternatives are sorted by the values S_i,R_i and Q_i in descending order.

Step 6. A compromise solution for the given set of criteria, the alternative $\left(a'\right)$ which is ranked the best by the measure the minimum Q_i is proposed if the following two conditions are satisfied (Tzeng et al., 2005):

C1: "Acceptable advantage": $Q\left(a''\right) - Q\left(a'\right) \geq D(Q)$ $Q\left(a''\right) - Q\left(a'\right) \geq D(Q)$ where $\left(a''\right)$ is the second alternative in the ranking list by Q_i and $D(Q) = 1/(K - 1)$; K represents the number of alternatives.

C2: "Acceptable stability in decision-making": Alternative $\left(a'\right)$ has to be best ranked by S or/and R.

If both conditions are satisfied, the alternative in the first rank is determined as the best alternative. If one of the conditions is not satisfied, then a set of compromise solutions is proposed (San Cristóbal, 2011):

- If C2 is not satisfied, Alternative $\left(a'\right)$ and Alternative $\left(a''\right)$;
- If C1 is not satisfied, Alternative $\left(a'\right)$, Alternative $\left(a''\right)$ … Alternative (Z) is determined by the relation $Q(Z) - Q\left(a'\right) < D(Q)$ for maximum Z.

The application

In 2020, 74 foundation and 129 state universities existed in Turkey. In the last decade, the number of students has increased more than twice in state universities and more than three times in foundation universities (YÖK, 2021c). Although there is an existing methodology for ranking universities in some countries, there is no such ranking system at the national level in Turkey. Furthermore, studies on university preference and classification for Turkey are quite few, and these studies are considered insufficient in terms of both scope and content. Kabak and Dağdeviren (Kabak & Dağdeviren, 2014) analyzed the factors for university selection and ranked universities in Turkey while only covering 15 universities and took the opinions of 50 students who are all engineering students. On the other hand, Erdoğmuş and Esen (2016) clustered Turkish universities according to different points of view. In the study by Erdoğmuş and Esen (2016), different weaknesses are faced in different clustering applications. For example, while universities were clustered according to their ranking scores, only 50 universities could be covered due to a lack of data; as for clustering in accordance with teaching performance, there was only one factor considered. Alternatively, global ranking systems mostly depend on academic research parameters (URAP Research Laboratory, 2021) and fail to satisfy being multidirectional. As distinct from the existing literature, this study provides the handling of both global and local characteristics of universities by clustering them according to academic and teaching characteristics and ranking them within the clusters considering student perspectives. The study has two main stages: (i) dividing universities into different groups and (ii) ranking them in each group separately. One hundred and ninety-one universities are clustered based on the teaching and research characteristics of universities. Clustering before ranking (i) ensures the impartial ranking of universities by only comparing universities that have students with similar expectations; (ii) can lead to getting smaller, more meaningful rankings instead of a multitude ranking which is difficult to interpret; (iii) prevents moving away from the reality of the ideal alternative that is needed for VIKOR by avoiding ranking many alternatives. Following the clustering, the universities are ranked through the proposed MCDM method for each cluster. The data reflecting the academic achivements of universities are collected from the official data of the Turkish Council of Higher Education (YÖK, 2021c) and SciVal tool provided by Elsevier (SciVal, 2021). The data that quantify students' satisfaction are collected from the report of Turkish Universities Satisfaction Research (Karadağ & Yücel, 2020) by UniAr (Karadağ & Yücel, 2021).

Clustering of Universities

As stated in the introduction, the foundation year is used to observe whether a longer service time of a university can lead to greater student satisfaction. The number of academicians of a university might be a kind of evidence for abundant sources that can be used for a wide range of demands. The number of academic outputs per academician is another factor in clustering universities. Here, academic output refers to the total number of articles, reviews, conference papers, books, and book chapters indexed in Scopus database. The other factors are considered signs of the academic outlook quality. Besides, these factors, which form the basis of our study for the clustering of universities, are factors that have been used frequently in previous studies to classify universities. Table 1 presents some examples of these studies that use these factors and their derivatives.

The factors are continuous and numerical variables. To ensure an equal contribution by the factors to the membership in a cluster, each factor is scaled according to Eq. 19 that normalizes the original values within the interval of [0,1].

$$x^p_{norm} = \frac{x^p - x^p_{\min}}{x^p_{\max} - x^p_{\min}} \tag{19}$$

where x^p_{norm} is a normalized value, and $x^p_{\max}$ and $x^p_{\min}$ are the extreme points of the pth factor x^p.

191 universities are divided based on the five normalized factors through agglomerative hierarchical clustering. For the best division, the most appropriate alternatives of

Table 1 Summary of related literature on similar factors in university clustering

Factor	Related sources
The number of academicians	Abbott and Doucouliagos (2003), Aliyev et al. (2020), Erdoğmuş and Esen (2016), Su et al. (2020), Valadkhani and Worthington (2006), Wang and Zha (2018)
The number of students per academician	Abbott and Doucouliagos (2003), Aliyev et al. (2020), Erdoğmuş and Esen (2016), Su et al. (2020), Wang and Zha (2018), Wu et al. (2012)
The number of academic outputs per academician	Abbott and Doucouliagos (2003), Alaşehir et al. (2014), Çakır et al. (2015), Chen and Chen (2010), Erdoğmuş and Esen (2016), Nazari-Shirkouhi et al. (2020), Porter, (1990), Valadkhani and Worthington (2006), Wang and Zha (2018), Wu et al. (2012)
The number of citations per academician	Alaşehir et al. (2014), Aliyev et al. (2020), Çakır et al. (2015), Su et al. (2020)
Foundation year	Erdoğmuş and Esen (2016), Soutar and Turner (2002)

hyperparameters are determined by testing all possible combinations of the number of clusters, distance metric, and linkage measures between clusters. The quality of clusters obtained for the combinations are compared over the mean silhouette score. The Silhouette score (Layton et al., 2013), which bases on the distance of an object to others in the same cluster and the distance of the object to objects in the nearest cluster, is a measure of cluster density.

The best combination of the hyperparameters for agglomerative clustering is determined according to 336 different combinations consisting of cluster numbers from 3 to 10; average, centroid, complete, median, single, Ward and Mcquaitty linkages and Euclidean, Manhattan, maximum, Pearson, Spearman and canberra distance metrics. Accordingly, the optimal hierarchical clustering hyperparameter set with the highest silhouette score 0.5071, as shown in Fig. 2, for the separation of the universities discussed in the study is as follows: 3 clusters, Euclidean distance and average linkage.

By the average linkage, the closeness between two clusters is defined as the average distance. The method averages the distances between each object in the first cluster and all objects in the second cluster (Yim & Ramdeen, 2015). Finally, the clusters that need to be combined are the two with the smallest average linkage distance calculated as in Eq. 20.

$$D(C_A, C_B) = \frac{1}{kl} \sum_{i=1}^{k} \sum_{j=1}^{l} \left\| \vec{x}_i - \vec{y}_j^2 \right\| \tag{20}$$

where $\vec{x}_i$ is a features vector for ith object of cluster C_A and $\vec{y}_j$ is a features vector for jth object of cluster C_B. k and l show cardinalities of the clusters C_A and C_B, respectively. $D(C_A, C_B)$ shows the average distance between clusters C_A and C_B that are candidates to be combined one.

The Euclidean distance d_{ij} between two objects presented as vectors with p elements that stand for the decision variables is calculated using Eq. 21.

$$d_{ij} = \sqrt{(x_{i1} - x_{j1})^2 + \cdots + (x_{ik} - x_{jk})^2 + \cdots + (x_{ip} - x_{jp})^2} \tag{21}$$

where x_{ik} and x_{jk} are the observed values corresponding to the kth decision variable of object i and object j, respectively.

The clusters and universities involved in the clusters are listed in Table 2. The universities are represented by abbreviations in their official web addresses (i.e., the web address of Acıbadem Mehmet Ali Aydınlar University is www.acibadem.edu.tr).

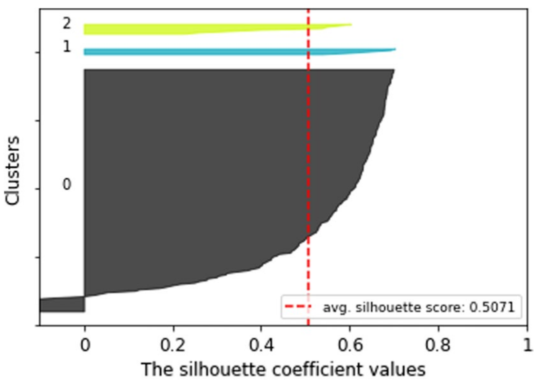


Fig. 2 The silhouette plot for the optimal hierarchical agglomerative clustering

The basic variation among the clusters can be seen in Fig. 3. The figure illustrates the spread of the factors according to the clusters.

According to Fig. 3, Cluster-1 consists of both state and foundation universities with a relatively low number of academicians. The universities in this cluster have lower outputs per academician, although some outliers exist. The universities in Cluster-1 probably fail to recruit a qualified and sufficient number of academics. Cluster-2 corresponds to well-established universities with a higher population of both academicians and students. The universities in Cluster-2 have a longer service-time (note that the smaller normalized factor value for the foundation year is the longer service-time). Cluster-3 and Cluster-1 are similar in terms of factors except for the citations per academician and output per academician. The universities gathered in Cluster-3 have the highest values of these normalized factors. In this regard, the universities in this cluster care about the success of academicians without concern for the number of academicians. Having a small number of successful academicians leads to the cluster having a high number of academic outputs per academician.

Table 2 The results of the clustering of universities

Cluster-1							
29mayis	artvin	biruni	fbu	iku	ksbu	ogu	thk
acibadem	asbu	bitliseren	firat	inonu	ksu	ohu	ticaret
adiyaman	atilim	bozok	gantep	isikun	ktu	okan	toros
adu	atu	btu	gedik	isparta	ktun	omu	trabzon
afsu	avrasya	cag	gelisim	istanbulc	sirnak	osmaniye	trakya
agri	aybu	cankaya	gi	iste	maltepe	tedu	ufuk
agu	aydin	comu	gidatarim	istinye	marmara	ozal	uludag
ahbv	ayvansaray	cu	giresun	iyte	mcbu	ozyegin	umeli
ahep	bakircay	cumhuriyet	gop	izu	medeniyet	pau	usak
ahievran	balikesir	subu	gsu	kafkas	medipol	pirireis	uskudar
akdeniz	bandirma	deu	gtu	kapadokya	mef	sakarya	yalova
akev	bartin	dicle	gumushane	karabuk	mehmetakif	samsun	yasar
aksaray	baskent	dogus	hakkari	karatay	mersin	sanko	yeditepe
aku	batman	dumlupinar	halic	karatekin	mgu	sbu	tau
alanya	bau	duzce	harran	kastamonu	mku	sdu	yildiz
alparslan	bayburt	ebyu	hitit	kayseri	msgsu	selcuk	sinop
altinbas	beun	erbakan	hku	kent	mu	siirt	yyu
amasya	beykent	erciyes	ibu	khas	munzur	yuksekihtisasuniversitesi	
anadolu	beykoz	erdogan	idu	kilis	nevsehir	lokmanhekim	
antalya	bezmialem	erzurum	ieu	kku	nisantasi	demiroglu.bilim	
ardahan	bilecik	esenyurt	igdir	klu	nku	tarsus	
arel	bilgi	eskisehir	ihu	kmu	nny	yeniyuzyil	
artuklu	bingol	fatihsultan	ikc	kocaeli	odu	ostimteknik	
Cluster-2							
ankara	atauni	ege	gazi	hacettepe	istanbul	itu	
Cluster-3							
bilkent	boun	etu	ku	sabanciu			

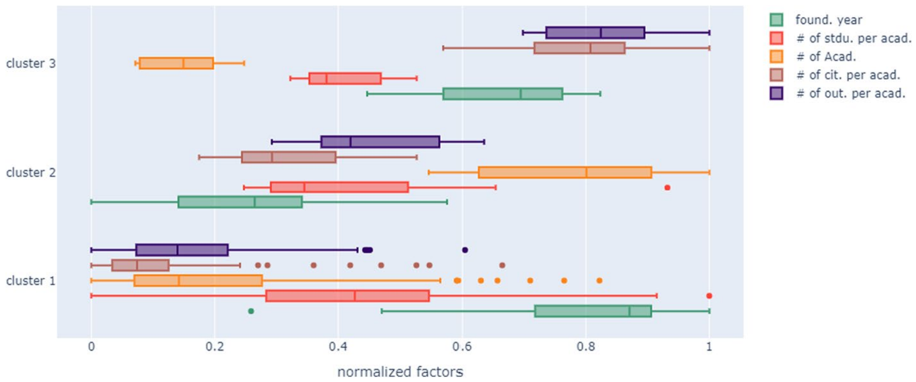


Fig. 3 The spread of each factor by clusters

Determination of the criteria weights

The proposed IVN-AHP VIKOR model was performed for Turkish universities. The criteria used for the ranking were adapted from the report of Turkish Universities Satisfaction Research (Karadağ & Yücel, 2020). The literature proves that these criteria are frequently used, as shown in Table 3.

In this study, the effects of the criteria discussed on total satisfaction might differ when evaluating universities from the student's point of view. Therefore, this study determines the weights of each criterion using the MCDM approach. Thus, it is aimed at obtaining more meaningful results by prioritizing the criteria while evaluating universities. In this respect, the study differs from articles oriented to university ranking based on student satisfaction in the literature. In addition, both the criterion weights and university evaluations were determined using MCDM approaches. In this study, for the first time in the literature, the VIKOR method is extended to the IVN-AHP method to solve complex decision-making problems. In this context, this study offers innovations in both theory and application.

The criteria are evaluated by 50 students from 13 different universities in Turkey to construct the pairwise comparison matrix. The students are asked to express their opinions to prioritize the criteria through a questionnaire. The students evaluate the criteria by using the linguistic variables given in Table 4. The interval-valued neutrosophic scale corresponding to the linguistic variables shown in Table 4 is used for this evaluation.

Pairwise comparison matrices for the criteria are constructed for each student. For example, the pairwise comparison matrix created by student-2 is given in Table 5.

First, the pairwise comparison matrices are tested for consistency, and the matrices found to be consistent are used to determine the criteria weights. At this point, 30 of 50 responses are determined to be consistent. After that, the calculations of IVN-AHP methodology are performed to determine the weights of the criteria considering each student. Then, the criteria weights determined based on the opinions of 30 different students are aggregated, and then the weights for each criterion are calculated as in Table 6. All students are accepted with an equal coefficient in the aggregation process.

Table 3 Summary of literature on the criteria for university selection from students' perspective

Criteria	References
Learning experience	Briggs (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Nojavan et al. (2021), Simões and Soares (2010), Sojkin et al. (2012), Soutar and Turner (2002)
Campus life	Briggs, (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Simões and Soares (2010), Sojkin et al. (2012), Soutar and Turner (2002)
Academic support	Briggs, (2006), Briggs and Wilson (2007), Castro-Lopez et al. (2021), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nojavan et al. (2021)
Management	Briggs and Wilson (2007), Goyal et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012)
Learning opportunities and resources	Briggs, (2006), Briggs and Wilson (2007), Goyal et al. (2021), Kabak and Dağdeviren (2014), Muhammad et al. (2021), Nanath et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012)
Personal development and career support	Briggs (2006), Briggs and Wilson (2007), Goyal et al. (2021), Kabak and Dağdeviren (2014), Nanath et al. (2021), Nojavan et al. (2021), Sojkin et al. (2012), Soutar and Turner (2002)

Table 4 Definition and IVN scales of the linguistic variables

Linguistic variables		T^L	T^U	I^L	I^U	F^L	F^U
Absolutely more important	AMI	0.9	0.95	0	0.05	0.05	0.15
Strongly more important	SMI	0.8	0.9	0.05	0.1	0.1	0.2
More important	MI	0.7	0.8	0.15	0.25	0.2	0.3
Weakly more important	WMI	0.6	0.7	0.25	0.35	0.3	0.4
Equal importance	EI	0.5	0.5	0.5	0.5	0.5	0.5
Weakly less important	WLI	0.4	0.5	0.55	0.65	0.5	0.6
Less important	LI	0.3	0.4	0.65	0.75	0.6	0.7
Strongly less important	SLI	0.2	0.3	0.75	0.85	0.7	0.8
Absolutely less important	ALI	0.1	0.2	0.9	0.95	0.8	0.9

Table 5 Pairwise comparison of the main criteria by student 2

	C1	C2	C3	C4	C5	C6
C1	EI	LI	WLI	SMI	WLI	WMI
C2	WMI	EI	MI	AMI	MI	SMI
C3	WMI	LI	EI	WMI	EI	WMI
C4	SLI	ALI	WLI	EI	WLI	WMI
C5	WMI	LI	EI	WMI	EI	MI
C6	WLI	SLI	WLI	WLI	LI	EI

Table 6 Aggregated weights of criteria

Criteria	Weight
Learning experience	0.1755
Campus and campus life	0.1528
Academic support and interest	0.1671
Management and operations	0.1631
Learning opportunities and resources	0.1698
Personal development and career support	0.1717

Ranking Universities with VIKOR

After the determination of the criteria weights, the opinions of the students for the evaluation of universities are provided from Turkish University Satisfaction Research (Karadağ & Yücel, 2020). In this framework, 39,386 undergraduate students' opinions are received from 191 different universities. While 125 state universities and 66 foundation universities are included, only two universities from Turkey could not be covered by this study due to their insufficient number of students.

In the report, student selection is conducted according to the quota sampling, and at least 75 students' opinions are taken from each university. According to quota sampling, different disciplinary students are reached. The most participating faculties are the Faculty of Engineering and Architecture with 17.8%, the Faculty of Economics and Administrative Sciences with 14.8%, and the Faculty of Science and Literature with 14.4%. In the questionnaire, participants are asked to evaluate the university at which they are studying according to six criteria on a Likert scale of 0–100 points. Thus, university evaluation matrices for each cluster are constructed for each criterion. The data used in this study are compiled from the UNIAR yearly report for 2020 (Karadağ & Yücel, 2020).

The universities are evaluated according to predetermined criteria for each cluster. Therefore, the VIKOR methodology is applied to rank universities for each cluster in Turkey. For this purpose, evaluation matrices are constructed for each cluster by categorizing the evaluations according to the obtained clusters. Firstly, the best and worst values of each criterion are determined for each cluster as given in Table 7. Therefore, the ideal solutions for each cluster are determined.

Sj, Rj and Qj are calculated using the weights obtained from IVN-AHP, and the ideal solutions given in Table 7 for each university and their rankings in their clusters are determined in this way. The S, R, and Q values of universities and their rankings according to these values are given in Tables 8, 9, 10 for Cluster-1, Cluster-2, and Cluster-3, respectively.

"ozyegin" is determined as the best university according to Qi scores. Both conditions are satisfied for Cluster-1. The ranks of other universities are given in Table 8 as the Q index for Cluster 1.

Again, two conditions are satisfied for Cluster 2. Therefore, "ege" is determined as the best university for Cluster 2. The ranks of other universities are given in Table 9 as the Q index for Cluster 2.

"sabanciu" is determined as the best university according to Qi scores. "sabanciu" satisfies the condition C2 (Acceptable stability in decision-making), because it is determined as

Table 7 The ideal solutions for each cluster

Cluster		C1	C2	C3	C4	C5	C6
Cluster-1	x_j^+	89	91	88	90	91	93
	x_j^-	30	34	36	34	35	35
Cluster-2	x_j^+	85	87	84	83	91	89
	x_j^-	58	62	63	61	75	70
Cluster-3	x_j^+	91	92	91	91	94	91
	x_j^-	68	72	69	58	71	69
General	x_j^+	91	92	91	91	94	93
	x_j^-	30	34	36	34	35	35

the best alternative for both S and Q. However, the condition C1 (Acceptable advantage) is not satisfied for "sabanciu". Since the condition C1 is not fulfilled for the "sabanciu", inequality of $Q\left(a''\right) - Q\left(a'\right) \geq D(Q)$ should be checked to find the compromise solution. Accordingly, the difference between "sabanciu" and "bilkent" is less than 0.2. For this reason, "sabanciu" and "bilkent" should be considered as compromise for the best university alternatives. If only one university is selected, "sabanciu", and if two universities are selected, "sabanciu" and "bilkent" should be determined as the best university together for Cluster 3. The ranks of other universities are given in Table 10 as the Q index.

Discussions and implications

The weights of six university service quality criteria are obtained using IVN-AHP methodology and then applied to the VIKOR model to determine the ranking index of the 191 universities in Turkey based on their clusters. Before applying the proposed MCDM methodology, clustering is performed for those universities.

The clustering method reveals that the universities are divided into 3 clusters. The result of the clustering is given in Table 2. Cluster-1, Cluster-2, and Cluster-3 include 178, 8, and 5 universities, respectively.

University Ranking by Academic Performance (URAP) has prepared a report taking the ranking values of 11 organizations that rank the leading universities worldwide. According to this report, 5 Turkish Universities ("itu", "hacettepe", "metu", "istanbul", "ankara") are existing in all of these rankings, 3 universities ("bilkent", "boun", "ege") are in ten lists, 1 university ("ku") is in nine lists and 2 universities ("sabanciu", "atatürk") are in eight lists. As for the results of the proposed clustering method, the universities that exist in all 11 organizations' lists of leading universities ("itu", "hacettepe", "metu", "istanbul", "ankara") are in the same cluster, namely Cluster-2. Besides, "ege," which belongs to 10 of the 11 lists, is also in Cluster-2. The remaining universities of Turkey that frequently existed in the leading universities lists appear in Cluster-3. Considering comparisons about university rankings, the result of the clustering method can be validated in this context.

The rankings of the universities in each cluster determined as a result of the proposed MCDM method are examined. According to Table 8, "ozyegin", "agu", and "acibadem" are ranked as the first, second, and third, respectively, in the same cluster. Although "ozyegin " and "acibadem" are foundation universities, and "agu" is a state university supported

Table 8 Rankings for Cluster-1

Uni		Qi		Si		Ri	Uni		Qi		Si		Ri
ozyegin	1	0.000	1	0.018	1	0.015	firat	90	0.495	90	0.421	94	0.105
agu	2	0.022	2	0.049	2	0.016	bakircay	91	0.497	87	0.414	96	0.107
acibadem	3	0.026	4	0.058	2	0.016	ufuk	92	0.500	95	0.456	87	0.101
mef	4	0.041	3	0.055	4	0.021	gop	93	0.505	93	0.445	93	0.104
gtu	5	0.057	6	0.084	4	0.021	kent	94	0.507	97	0.463	90	0.102
pirireis	6	0.066	7	0.085	6	0.024	uskudar	95	0.511	98	0.469	91	0.102
iyte	7	0.088	5	0.082	8	0.032	beykent	96	0.512	101	0.479	87	0.101
bilgi	8	0.089	8	0.100	7	0.029	ahievran	97	0.514	107	0.521	84	0.094
ieu	9	0.123	13	0.139	10	0.033	afsu	98	0.517	102	0.480	91	0.102
khas	10	0.133	17	0.163	9	0.033	erdogan	99	0.527	96	0.457	98	0.109
akdeniz	11	0.136	11	0.116	16	0.041	tarsus	100	0.545	88	0.420	110	0.121
bezmialem	12	0.138	10	0.112	17	0.043	cag	101	0.557	99	0.477	102	0.115
mu	13	0.141	16	0.161	11	0.036	nisantasi	102	0.557	100	0.477	102	0.115
yildiz	14	0.144	12	0.135	14	0.041	mku	103	0.558	106	0.516	100	0.109
maltepe	15	0.145	14	0.151	12	0.038	anadolu	104	0.564	74	0.348	139	0.140
yasar	16	0.149	15	0.153	13	0.039	usak	105	0.573	104	0.490	107	0.118
gsu	17	0.154	9	0.108	21	0.049	dumlupinar	106	0.586	108	0.532	102	0.115
ktun	18	0.173	24	0.190	14	0.041	atu	107	0.587	103	0.482	114	0.124
iku	19	0.182	22	0.186	18	0.044	ibu	108	0.590	110	0.539	102	0.115
tedu	20	0.193	23	0.190	20	0.047	btu	109	0.592	105	0.508	110	0.121
ktu	21	0.194	28	0.208	18	0.044	cankaya	110	0.595	112	0.548	102	0.115
comu	22	0.199	18	0.166	28	0.053	kku	111	0.601	122	0.598	98	0.109
cu	23	0.209	26	0.195	25	0.051	ohu	112	0.609	114	0.555	108	0.119
iste	24	0.209	19	0.183	33	0.054	kafkas	113	0.616	113	0.549	112	0.122
kocaeli	25	0.212	27	0.208	22	0.050	ksu	114	0.631	115	0.558	115	0.125
sbu	26	0.213	21	0.185	34	0.055	avrasya	115	0.632	123	0.598	109	0.119
mersin	27	0.218	32	0.220	22	0.050	toros	116	0.636	111	0.539	125	0.130

Table 8 (continued)

Uni		Qi		Si		Ri	Uni		Qi		Si		Ri
isikun	28	0.222	29	0.209	28	0.053	kastamonu	117	0.637	116	0.558	119	0.127
29mayis	29	0.223	30	0.211	28	0.053	aku	118	0.638	121	0.590	112	0.122
erciyes	30	0.227	20	0.183	36	0.059	kmu	119	0.641	117	0.565	116	0.127
karatay	31	0.227	37	0.229	27	0.052	artuklu	120	0.641	118	0.566	116	0.127
marmara	32	0.236	39	0.234	32	0.054	isparta	121	0.660	119	0.567	130	0.133
omu	33	0.238	45	0.257	22	0.050	istinye	122	0.662	109	0.535	137	0.139
demiroglu.bilim	34	0.240	25	0.194	42	0.062	samsun	123	0.667	126	0.615	119	0.127
sdu	35	0.242	43	0.247	28	0.053	klu	124	0.671	120	0.587	130	0.133
balikesir	36	0.243	46	0.260	25	0.051	lokmanhekim	125	0.672	125	0.601	128	0.131
tau	37	0.247	31	0.214	39	0.061	ahbv	126	0.675	128	0.627	122	0.128
ihu	38	0.254	40	0.236	35	0.059	gedik	127	0.678	127	0.617	125	0.130
hku	39	0.257	36	0.229	41	0.061	nevsehir	128	0.680	124	0.600	132	0.134
odu	40	0.263	42	0.243	39	0.061	sinop	129	0.687	132	0.653	119	0.127
aybu	41	0.264	34	0.226	45	0.064	amasya	130	0.700	138	0.676	116	0.127
mehmetakif	42	0.269	38	0.229	47	0.065	ayvansaray	131	0.708	137	0.675	124	0.130
trakya	43	0.270	44	0.248	43	0.062	osmaniye	132	0.714	139	0.685	125	0.130
ikc	44	0.270	41	0.237	45	0.064	subu	133	0.722	144	0.711	123	0.129
selcuk	45	0.271	47	0.267	36	0.059	agri	134	0.723	131	0.652	136	0.139
uludag	46	0.282	48	0.268	44	0.062	beun	135	0.725	129	0.635	143	0.143
fatihsultan	47	0.282	35	0.226	52	0.070	bilecik	136	0.735	140	0.691	133	0.136
mcbu	48	0.285	56	0.293	36	0.059	ostimteknik	137	0.735	147	0.718	129	0.132
ogu	49	0.308	55	0.290	50	0.067	trabzon	138	0.740	130	0.646	150	0.146
yyu	50	0.314	58	0.303	49	0.067	eskisehir	139	0.740	133	0.662	143	0.143
antalya	51	0.318	66	0.321	47	0.065	gi	140	0.743	134	0.669	143	0.143
yeditepe	52	0.318	49	0.277	54	0.073	ozal	141	0.745	142	0.706	134	0.137

Table 8 (continued)

Uni		Qi		Si		Ri	Uni		Qi		Si		Ri
sanko	53	0.323	33	0.224	71	0.083	siirt	142	0.746	141	0.700	135	0.138
okan	54	0.327	54	0.286	56	0.074	alanya	143	0.746	136	0.674	140	0.142
ticaret	55	0.332	68	0.329	51	0.068	bozok	144	0.756	135	0.674	152	0.146
medipol	56	0.334	60	0.306	54	0.073	aydin	145	0.765	146	0.712	140	0.142
baskent	57	0.337	67	0.321	53	0.071	ahep	146	0.767	150	0.733	137	0.139
biruni	58	0.341	53	0.284	62	0.079	ebyu	147	0.774	149	0.729	140	0.142
gantep	59	0.344	64	0.316	57	0.074	ardahan	148	0.782	145	0.711	153	0.148
inonu	60	0.349	52	0.283	70	0.082	artvin	149	0.790	152	0.740	150	0.146
atilim	61	0.350	57	0.301	62	0.079	gidatarim	150	0.792	143	0.708	159	0.152
pau	62	0.356	50	0.279	72	0.084	aksaray	151	0.796	156	0.767	143	0.143
istanbulc	63	0.356	59	0.304	68	0.080	alparslan	152	0.801	148	0.724	161	0.152
harran	64	0.357	72	0.340	57	0.074	gumushane	153	0.804	158	0.768	148	0.145
beykoz	65	0.359	61	0.308	68	0.080	arel	154	0.808	153	0.759	153	0.148
medeniyet	66	0.359	65	0.318	62	0.079	halic	155	0.809	161	0.779	148	0.145
izu	67	0.361	51	0.280	75	0.086	adiyaman	156	0.813	159	0.769	153	0.148
nku	68	0.370	69	0.332	67	0.080	bingol	157	0.814	157	0.768	157	0.149
hitit	69	0.375	76	0.358	59	0.077	yalova	158	0.814	154	0.767	158	0.149
altinbas	70	0.381	77	0.359	62	0.079	thk	159	0.815	163	0.792	147	0.145
giresun	71	0.382	80	0.371	61	0.077	idu	160	0.832	162	0.783	159	0.152
nny	72	0.386	79	0.369	62	0.079	karatekin	161	0.832	155	0.767	162	0.155
adu	73	0.387	81	0.383	59	0.077	fbu	162	0.834	165	0.808	153	0.148
ihtisas	74	0.388	70	0.336	73	0.085	mgu	163	0.842	151	0.734	172	0.163
bau	75	0.393	63	0.311	80	0.091	dogus	164	0.853	160	0.770	169	0.161
bandirma	76	0.403	78	0.360	74	0.086	umeli	165	0.862	164	0.793	166	0.160
kapadokya	77	0.408	75	0.353	78	0.089	batman	166	0.869	166	0.823	164	0.157

Table 8 (continued)

Uni		Qi		Si		Ri	Uni		Qi		Si		Ri
sakarya	78	0.409	62	0.310	85	0.096	kayseri	167	0.875	169	0.848	162	0.155
deu	79	0.417	73	0.342	82	0.093	kilis	168	0.880	168	0.840	165	0.158
karabuk	80	0.430	86	0.399	77	0.088	sirnak	169	0.900	171	0.859	169	0.161
bartin	81	0.435	82	0.386	81	0.092	yeniyuzyil	170	0.900	172	0.862	168	0.160
erbakan	82	0.437	85	0.397	79	0.090	igdir	171	0.901	170	0.848	171	0.163
dicle	83	0.442	91	0.429	76	0.087	munzur	172	0.902	174	0.868	166	0.160
ksbu	84	0.458	89	0.421	82	0.093	gelisim	173	0.917	167	0.838	176	0.170
msgsu	85	0.476	83	0.387	94	0.105	bayburt	174	0.921	173	0.863	173	0.167
asbu	86	0.478	71	0.339	101	0.114	esenyurt	175	0.934	176	0.888	173	0.167
erzurum	87	0.487	84	0.393	97	0.107	bitliseren	176	0.940	175	0.883	175	0.170
cumhuriyet	88	0.488	92	0.443	86	0.099	hakkari	177	0.988	177	0.938	178	0.176
duzce	89	0.494	94	0.445	87	0.101	akev	178	0.988	178	0.961	177	0.172

Table 9 Rankings for Cluster-2

Uni		Qi		Si		Ri
ege	1	0.030	2	0.072	1	0.033
hacettepe	2	0.179	3	0.176	2	0.052
itu	3	0.205	1	0.033	4	0.091
gazi	4	0.280	5	0.247	3	0.065
istanbul	5	0.381	6	0.260	4	0.091
metu	6	0.568	4	0.208	7	0.156
ankara	7	0.737	7	0.455	6	0.150
atauni	8	1.000	8	0.676	8	0.176

Table 10 Rankings for Cluster-3

Uni		Qi		Si		Ri
sabanciu	1	0.034	1	0.031	2	0.046
bilkent	2	0.037	2	0.107	1	0.031
boun	3	0.164	4	0.191	3	0.069
ku	4	0.193	3	0.145	4	0.092
etu	5	1.000	5	1.061	5	0.252

by the foundation, the common feature of these three universities is that the amount of expenditure per student is more than 20,000 Turkish Lira (YÖK, 2021b). In the same cluster, "akev", "hakkari" and "bitliseren" universities are ranked as the last three universities. A possible explanation for this might be that they are located in cities far from the metropolitans and have not developed industrial areas. The fact that the program occupancy rates of these universities are 64%, 81%, and 67% also confirms their place in the ranking.

As for Cluster-2, all universities except "atauni" are located in the three biggest cities of Turkey in terms of industry and population. The reason "atauni" placed last in the ranking may arise from the location of the university, a relatively underdeveloped city in a remote area. It is not surprising that "atauni" gets the lowest evaluations of the criteria "Personal Development and Career Support" and "Learning Opportunities and Resources" considering the location of the university. On the other hand, universities that are in the first three places, "ege", "hacettepe", and "itu", are outstanding in terms of overall program occupancy rate. While "ege" surpassses other universities in Cluster-2 in especially the "Management and Operations" and "Academic Support and Interest" criteria, "hacettepe" never comes first in accordance to any criteria yet comes really close to the best values in each criterion. The fact that "metu", one of the best universities in Turkey, is ranked sixth in this cluster shows that student satisfaction is relatively low.

When examining Cluster-3, "sabanciu" can be seen in the first place. The fact that "sabanciu" has a 98% overall program occupancy rate even though it is a foundation university corroborates this result. Furthermore, the number of students from the university of "sabanciu" participating in Technocity or Technology Transfer Office (TTO) projects and industrial projects is more than twice times higher as the universities within the same cluster. For "bilkent", which is in the second place, it can be concluded that it offers a vibrant social environment for students, as it has the second highest number of sports facilities and the highest number of student societies. Additionally, "bilkent" is the second-highest in its cluster in terms of the number of faculty members, while it ranks first on foreign academic staff. The fact that the university of "etu" has the lowest number of faculty members, foreign academic staff, sports facilities, and student societies compared to other universities in Cluster 2, justifies the rank of last place in accordance to the satisfaction of students (YÖK, 2021a).

General ranking

Finally, considering the nonclustering case, all universities are evaluated using the VIKOR method and ranked. In this scenario, all 191 universities are evaluated together via VIKOR. The comparison of the general ranking and cluster-based ranking is given in Table 11. The universities in Cluster-2 and Cluster-3 are highlighted with red and green, respectively.

The positions of the universities in the overall rankings are not always consistent with their positions in the cluster-based rankings, as expected. While "sabanciu" is determined as the best university in its cluster (Cluster-3), it ranks second in overall ranking. Conversely, "bilkent" ranks second in its cluster-based ranking and first in the overall ranking. The negative ideal alternative for Cluster-3 is represented by the values of S^{-}=1.061 and R^{-}=0.252, which has coincided with the "etu" university. Although there is no significant difference between them, "sabanciu" is farther from the negative ideal alternative ($Q_{\text{sabanciu}}=0.034$, $Q_{\text{bilkent}}=0.037$) in its cluster. In the overall ranking, the negative ideal alternative is represented with the values of S^{-} = 0.961 and R^{-} = 0.176. The negative ideal alternative that does not correspond to the existing universities is very similar to the "hakkari" and "akev" universities. This time, "sabanciu" is closer to the negative ideal with $Q_{\text{sabanciu}}=0.019$ compared to "bilkent" with $Q_{\text{bilkent}}=0.016$.

In other words, the distance from the negative ideal alternative "sabanciu", which is determined as the best university in cluster 3, is even more affected than "bilkent", which is determined as the second-best university in the cluster. This situation stems from the difference between the R values of the two universities. For this reason, the rankings have changed for the non-clustering case.

Sensitivity analysis

A sensitivity analysis is conducted to show the reliability, robustness, and applicability of the proposed methodology due to changes in the parameter values. The threshold value (v) used in VIKOR is changed to perform sensitivity analysis. The analysis is performed for Cluster-2. In each scenario, the threshold value is increased by 0.1 starting from 0.1 and till 0.9 and the Q_i score of each university is recalculated. The changes in the Q_i scores according to different threshold values are shown in Fig. 4.

Then final rankings of universities are determined according to updated scores and shown in Fig. 5 for different threshold values.

The effect of threshold value on university ranking is analyzed via sensitivity analysis. The reason for the changes in the ranking is that the universities have S_i (the weighted total regret) and R_i (the weighted maximum regret) values. As shown in Fig. 5, "ege" which is the best university in the current situation, is determined as the best university for all threshold values except 0.9. This means "ege" can be evaluated as student-friendly university. The ranking of "itu", which currently takes the fourth place, increases while the threshold value increases; so it becomes the second-best university for 0.9. The reason for this is that "itu" has bad value for S_i (the weighted total regret). As the threshold value

Table 11 In-cluster and general ranking of universities

GR	Uni	CR	GR	Uni	CR	GR	Uni	CR	GR	Uni	CR
1	**bilkent**	**2**	49	mehmetakif	42	97	ksbu	84	145	osmaniye	132
2	**sabanciu**	**1**	50	aybu	41	98	msgsu	85	146	agri	134
3	ozyegin	1	51	selcuk	45	99	asbu	86	147	beun	135
4	agu	2	52	trakya	43	100	erzurum	87	148	subu	133
5	acibadem	3	53	ikc	44	101	cumhuriyet	88	149	bilecik	136
6	mef	4	54	odu	40	102	duzce	89	150	ostimteknik	137
7	**boun**	**3**	55	fatihsultan	47	103	firat	90	151	eskisehir	138
8	gtu	5	56	mcbu	48	104	ufuk	92	152	trabzon	139
9	**ku**	**4**	57	uludag	46	105	bakircay	91	153	gi	140
10	pirireis	6	58	ogu	49	106	kent	94	154	ozal	141
11	iyte	7	*59*	*metu*	*6*	107	beykent	96	155	siirt	142
12	bilgi	8	60	yyu	50	108	gop	93	156	alanya	143
13	*ege*	*1*	61	antalya	51	109	uskudar	95	157	bozok	144
14	akdeniz	11	62	yeditepe	52	110	afsu	98	158	aydin	145
15	khas	10	63	sanko	53	111	ahievran	97	159	ahep	146
16	mu	13	64	okan	54	112	erdogan	99	160	ebyu	147
17	bezmialem	12	65	baskent	57	113	tarsus	100	161	ardahan	148
18	ieu	9	66	medipol	56	114	nisantasi	102	162	artvin	149
19	maltepe	15	67	ticaret	55	115	cag	101	163	gidatarim	150
20	yildiz	14	*68*	*ankara*	*7*	116	anadolu	104	164	aksaray	151
21	yasar	16	69	inonu	60	117	mku	103	165	alparslan	152
22	gsu	17	70	gantep	59	118	usak	105	166	gumushane	153
23	*hacettepe*	*2*	71	biruni	58	119	dumlupinar	106	167	arel	154
24	ktun	18	72	istanbulc	63	120	ibu	108	168	halic	155
25	*itu*	*3*	73	pau	62	121	atu	107	169	adiyaman	156
26	iku	19	74	izu	67	122	cankaya	110	170	yalova	158
27	tedu	20	75	beykoz	65	123	btu	109	171	bingol	157
28	*gazi*	*4*	76	atilim	61	124	kku	111	172	thk	159
29	ktu	21	77	harran	64	125	ohu	112	173	fbu	162
30	comu	22	78	nku	68	126	kafkas	113	174	idu	160
31	kocaeli	25	79	medeniyet	66	127	ksu	114	175	karatekin	161
32	iste	24	80	hitit	69	128	avrasya	115	176	mgu	163
33	mersin	27	81	adu	73	129	kmu	119	177	dogus	164
34	isikun	28	82	altinbas	70	130	aku	118	178	umeli	165
35	29mayis	29	83	giresun	71	131	artuklu	120	179	batman	166
36	erciyes	30	84	nny	72	132	toros	116	180	kayseri	167
37	cu	23	85	yuksekihtisas	74	133	kastamonu	117	181	kilis	168
38	sbu	26	86	bau	75	134	isparta	121	182	yeniyuzyil	170
39	*istanbul*	*5*	87	bandirma	76	135	istinye	122	183	igdir	171
40	omu	33	88	kapadokya	77	136	klu	124	184	sirnak	169
41	sdu	35	89	sakarya	78	137	samsun	123	185	munzur	172
42	demiroglu.bilim	34	90	deu	79	138	lokmanhekim	125	186	gelisim	173
43	karatay	31	91	bartin	81	139	ahbv	126	187	bayburt	174
44	marmara	32	92	erbakan	82	140	nevsehir	128	188	esenyurt	175
45	ihu	38	93	karabuk	80	141	gedik	127	189	bitliseren	176
46	balikesir	36	**94**	**etu**	**5**	142	sinop	129	190	akev	178
47	hku	39	*95*	*atauni*	*8*	143	amasya	130	191	hakkari	177
48	tau	37	96	dicle	83	144	ayvansaray	131			

Table 11 (continued)

CR cluster ranking; *GR* general ranking; Universities in italics are in Cluster-2, and universities in bold are in Cluster-3

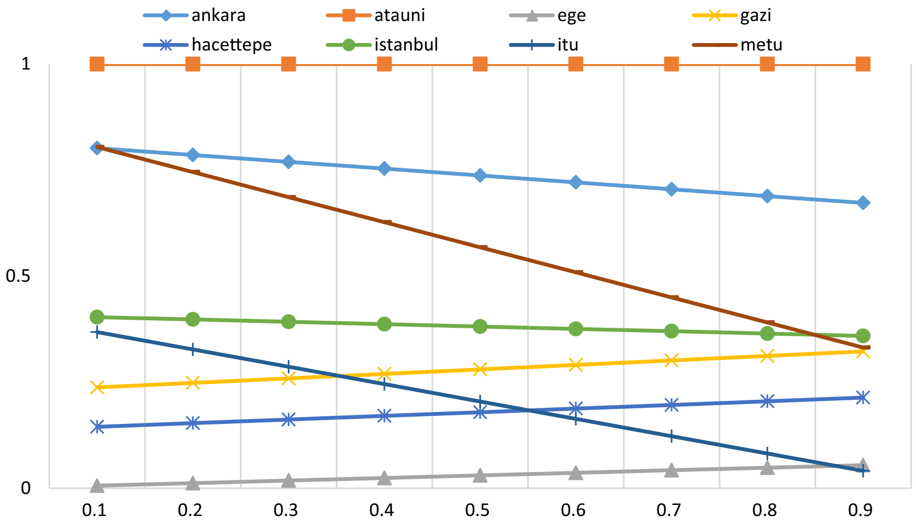
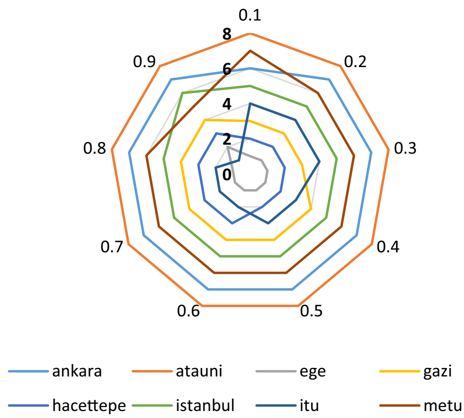


Fig. 4 The changes in the Q_i scores

Fig. 5 The ranking of alternatives according to different threshold values



increases, the effect of the S_i decreases. "atauni" is determined as the worst university in Cluster-2 for all scenarios.

Conclusion

The competition between universities is getting challenging with the increasing number of institutions. Therefore, universities should improve themselves in areas such as research and education and even make improvements by taking student satisfaction into account. In this study, a novel framework is established to address university ranking. In this framework, the clustering of universities according to teaching and research characteristics is performed in the first stage, and ranking universities according to student satisfaction, in-cluster and general, is obtained in the second stage. Six factors representing the characteristics of universities in the teaching and research areas were used in the clustering analysis: “foundation year”, “the number of academicians”, “the number of students per academician”, “the number of citations per academician”, and “the number of outputs per academician”. In the second stage, to prioritize the evaluation criteria which are "learning experience", " campus life", "academic support and interest", "management ", "learning opportunities and resources", and "personal development and career support”, IVN-AHP is used. The results of IVN-AHP are used in the VIKOR method as criteria weights to reveal the ranking.

The contributions of this study to the literature can be summarized as follows: (1) A novel clustering-based MCDM methodology is presented to handle MCDM problems with more alternatives; (2) Both global and local characteristics of universities are handled together; (3) The factors related to university segmentation are determined by literature review; (4) The most important criteria regarding university ranking by student satisfaction are determined by IVN-AHP; (5) The university ranking problem is modeled as an MCDM problem; (6) A brief literature review on university ranking problem is presented; (7) The universities from Turkey are clustered by hierarchical clustering; (8) Universities are evaluated and ranked through VIKOR; (9) To the best of our knowledge, this paper presents IVN-AHP integrated VIKOR methodology for the first time; (10) A real case application for evaluating universities in Turkey is presented to show the applicability of the proposed methodology.

The results show that there is no significant difference between the weights of the criteria that affect students’ perceptions of university satisfaction, while "learning experience" is the most important criterion, followed by "personal development and career support" and "learning opportunities and resources". In other respects, the fact that foundation universities take most of the first places is a valuable insight for authorized institutions such as The Council of Higher Education (YÖK). Moreover, the results of this study have guiding features for universities in Turkey, as they show their position in terms of student satisfaction.

The proposed hybrid methodology can be used to solve complex decision-making problems. The quality of services in different public or private institutions can be evaluated using the proposed MCDM approach. The proposed methodology can also be applied to different types of educational institution, such as primary school, high school. This study can be expanded by interviewing more experts or the number of factors and/or criteria can be increased.

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Code Availability Not applicable.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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